PRO-SET®

The New Standard

PRO-SET EPOXIES for Laminating, Infusion, Tooling and Assembly

| Wessex Resins & Adhesives, Cupernham Lane, Romsey, Hampshire, SO51 7LF, UK |
| pro-set.co.uk | +44 (0) 1794 521111

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Cover: REINDEER V, designed by Chuck Paine & Assoc., built by Boston Boatworks and Morris Yacht's Custom Division. Photo by: Art Paine

INTRODUCTION

Use PRO-SET Epoxy to create strong, lightweight composites that can withstand the harshest environments. PRO-SET meets your highest goals in composite performance.

We are reformulating and expanding our standard PRO-SET epoxy product offerings to best meet the needs of modern, high-performance composite manufacturing.

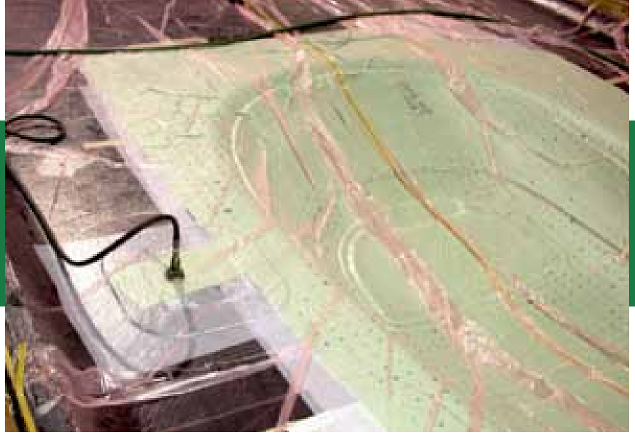
Standard PRO-SET Epoxies for Laminating, Infusion, Tooling and Assembly offer improved handling characteristics, excellent cure profiles, and rapid order fulfillment at competitive prices.

This guide provides an overview of the PRO-SET products with a comparison of resin and hardener handling characteristics and cured properties, and a general PRO-SET Epoxy Handling Guide. Refer to the specific combined Resin/Hardener Technical Data Sheets for detailed handling, ratio, mechanical and thermal property information.

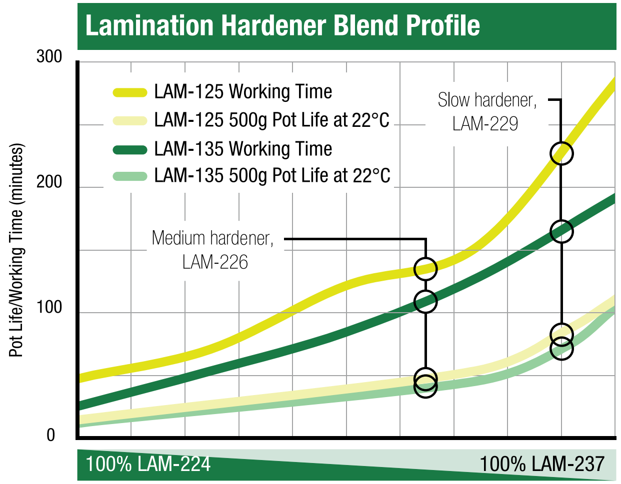
Custom Formulation

PRO-SET can formulate custom resin and hardener systems tailored to your specific processes and performance needs, working closely with you throughout the development of your custom formulation. Turnaround times are generally rapid, with only slightly extended lead times required once your custom formulation is placed into production. PRO-SET custom formulations usually require minimum volumes, and these products are typically made available under our Custom Formulations category, unless the customer specifies them as proprietary.

LAMINATING EPOXIES



Vacuum lamination in progress



Hardeners may be blended for targeted cure time.

PRO-SET Laminating Epoxies	
Choose one of four PRO-SET Resins by viscosity	
Low Viscosity Laminating Resin	LAM-125
Medium Viscosity Laminating Resin	LAM-135
Thixotropic Laminating Resin	LAM-145
Choose one of four PRO-SET Hardeners by cure speed	
Fast Laminating Hardener	LAM-224
Medium Laminating Hardener	LAM-226
Slow Laminating Hardener	LAM-229
Extra Slow Laminating Hardener	LAM-237

PRO-SET Laminating Epoxies are a versatile system of liquid resins and hardeners designed to meet a wide range of wet lay-up laminating applications.

Use PRO-SET Laminating Epoxies to produce lightweight, high-performance composite structures that will withstand long-term cyclic loading in the harshest environments. These epoxies bond to core materials, wood, metal and all reinforcing fabrics. They offer excellent moisture resistance, toughness and superior resistance to heat and fatigue. **PRO-SET Laminating Epoxies develop excellent physical properties at room temperature** and may be post-cured for enhanced performance.

LAM Resin Selection

Property	Standard	Units	LAM-125 Resin[1]	LAM-135 Resin[1]	LAM-145 Resin[1]
Mix Ratio by Volume		R:H	3:1	3:1	3:1
Mix Ratio by Weight		R:H	3.5:1	3.5:1	3.5:1
Mixed Viscosity @ 25°C	ASTM D2196	mPas	449–616	904–1705	1495–2059
Mixed Density @ 22°C		g/cc	1.16	1.17	1.17
Shear Thinning Index	ASTM D2196	RPM Rotation			1.37
Compression Yield	ASTM D695	MPa)	~96	~101	~101
Tensile Strength	ASTM D638	MPa	~70	~74	~75
Tensile Modulus	ASTM D638	GPa	~3.19	~3.19	~3.19
Tensile Elongation	ASTM D638	%	~5.6	~6.2	~6.2
Flexural Strength	ASTM D790	MPa	~124	~128	~128
Flexural Modulus	ASTM D790	GPa	~3.12	~3.03	~3.03
Tg Ultimate via DMA[3]	ASTM E1640[3]	°C	>89	>102	>102
Tg Ultimate via DSC with LAM-251-HT Hardener[2]	ASTM E1640[3]	°C	135	142	142

[1]Average of properties for combinations with LAM-224, LAM-226, LAM-229 and LAM-237 Hardeners.
2Additional post cure may be required; contact the Wessex Resins Technical Staff for details.
[4]1 HZ, 3˚C per minute

Typical Physical Properties Comparison Guide

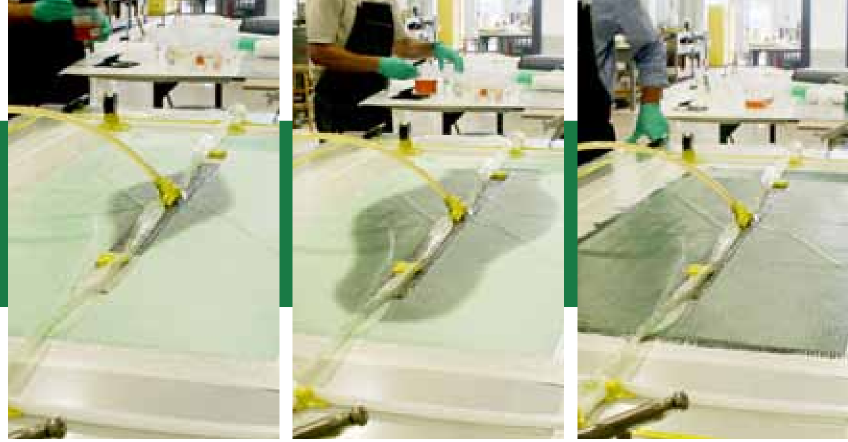
Test specimens are cured at room temperature to gelation and 82°C for eight hours, unless otherwise noted. Neat epoxy samples are used for testing. See Resin/Hardener Technical Data Sheet for exact values. Typical values, not to be construed as specifications.

LAM Hardener Selection

Property	Standard	LAM-224 Hardener	LAM-226 Hardener	LAM-229 Hardener	LAM-237 Hardener
150g Pot Life @ 25°C	ASTM D2471	13 min	52–59 min	93–100 min	128–163 min
500g Pot Life @ 25°C	ASTM D2471	12 min	45–52 min	73–84 min	102–107 min
Approx. working time @ 25°C		40 min	2–3 hr	4–5 hr	7–8 hr

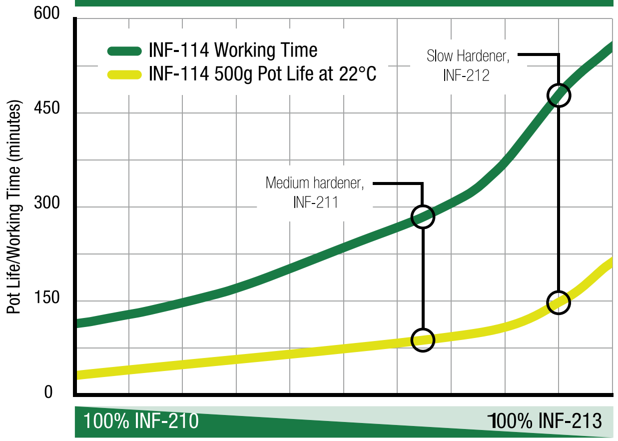
Hardeners can be blended for intermediate cure times (see chart previous page).

INFUSION EPOXIES



Infusion process

Infusion Hardener Blend Profile



Hardeners may be blended for targeted cure time.

PRO-SET Infusion Epoxies	
Resins	
Infusion Resin	INF-114
Hardeners	
Fast Infusion Hardener	INF-210
Medium Infusion Hardener	INF-211
Slow Infusion Hardener	INF-212
Extra Slow Infusion Hardener	INF-213

PRO-SET Infusion Epoxies are super low viscosity systems with a range of hardeners to meet the demands of modern infusion processes.

PRO-SET Infusion Epoxies result in lightweight, high performance composites that will withstand long term cyclic loading in the harshest environments. PRO-SET Infusion Epoxies **develop excellent physical properties at room temperature** and may be post-cured to further enhance performance.

INF Resin Selection

Property	Standard	Units	INF-114 Resin[1]
Mix Ratio by Volume		R:H	3:1
Mix Ratio by Weight		R:H	~3.65:1
Mixed Viscosity @ 25°C	ASTM D2196	mPas	~245
Mixed Density @ 22°C		gcm-3	~1.14
Compression Yield	ASTM D695	MPa	~97.0
Tensile Strength	ASTM D638	MPa	~71.3
Tensile Modulus	ASTM D638	GPa	~3.38
Tensile Elongation	ASTM D638	%	~4.95
Flexural Strength	ASTM D790	MPa	~123.7
Flexural Modulus	ASTM D790	GPa	~3.19
Tg Ultimate via DMA[2]	ASTM E1640[3]	°C	>85.2

As of press time, TBD values are undergoing testing.
[1]Average of properties for combinations with INF-210, INF-211, INF-212 and INF-213 Hardeners.
[2]Additional post cure may be required; contact the Wessex Resins Technical Staff for details.
[3]1 HZ, 3°C per minute

Typical Physical Properties Comparison Guide

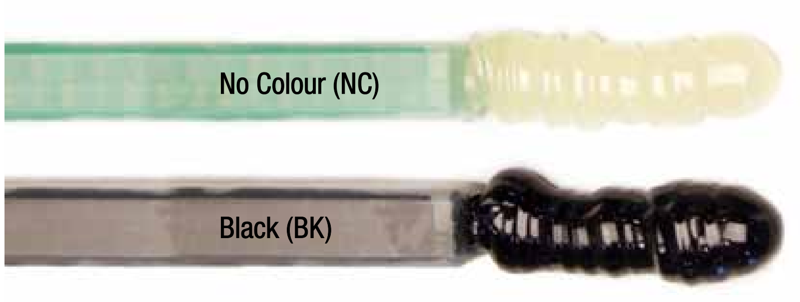
Test specimens are cured at room temperature to gelation and 82°C for eight hours, unless otherwise noted. Neat epoxy samples are used for testing. See Resin/Hardener Technical Data Sheet for exact values. Typical values, not to be construed as specifications.

INF Hardener Selection

Property	Standard	INF-210 Hardener	INF-211 Hardener	INF-212 Hardener	INF-213 Hardener
150g Pot Life @ 25°C	ASTM D2471	27 min	122 min	185 min	262 min
500g Pot Life @ 25°C	ASTM D2471	25 min	85 min	132 min	175 min
Approx. working time @ 25°C		75–90 min	3–4 hr	6–7 hr	10 hr

Hardeners can be blended for intermediate cure times (see chart previous page).

ADHESIVE EPOXIES



PRO-SET Adhesive Epoxies	
General Purpose Adhesive Resin	ADV-170-R
General Purpose Adhesive Hardener	ADV-170-H
Fast Adhesive No Colour	ADV-175/273-NC
Fast Adhesive Black	ADV-175/273-BK
Medium Adhesive No Colour	ADV-175/275-NC
Medium Adhesive Black	ADV-175/275-BK
Slow Adhesive No Colour	ADV-175/277-NC
Slow Adhesive Black	ADV-175/277-BK
Toughened Adhesive No Colour	ADV-176/276-NC
Toughened Adhesive Black	ADV-176/276-BK

PRO-SET Assembly Adhesives are pre-thickened, two-part epoxy adhesives used for secondary bonding of laminated composites as well as steel, aluminium, cast iron, concrete, stone, and most woods.

PRO-SET ADV-170 Adhesive is extremely versatile and has been developed for general purpose bonding of a veriety or materials. This adhesive has proved remarkably popular for bonding of teak decking. Both the resin and hardener componets are thixotropic pastes and the adhesive is avalible in a range of pack sizes.

Adhesives based on PRO-SET 175 Resin are paired with Fast (273), Medium (275) or Slow (277) hardener. They are suitable for most composite bonding applications.

PRO-SET ADV-176/276 Toughened Adhesive delivers exceptional toughness and superior peel strength for heavily loaded applications and difficult-to-bond substrates including pre-preg, sheet moulding compound, metals and most plastics.

The PRO-SET ADV-175 and ADV-176 series of Assembly Adhesives are packaged in 400 ml two-component cartridges and in bulk container sizes and are available in No Colour (NC) and Black (BK).

ADV Combined Resin/Hardener Selection

Property	Standard	Units	ADV-170-R/ ADV-170-H General Purpose Adhesive	ADV-175 Resin ADV-273 Fast Hardener	ADV-175 Resin ADV-275 Medium Hardener	ADV-175 Resin ADV-277 Slow Hardener	ADV-176/ ADV-276 Toughened Adhesive
Mix Ratio by Volume		R:H	1:1	2:1	2:1	2:1	2:1
Working Time, 12.5mm bead @ 22°C		minutes	120 min	20 min	75 min	150 min	90 min
Hardness	ASTM-D2240	Shore D	81	82	85	84	79
Compression Yield	ASTM-D695	MPa	57	74	87	81	59
Tensile Strength	ASTM-D638	MPa	33	43	54	49	35
Tensile Modulus	ASTM-D638	GPa	2.6	2.6	3.6	2.9	2.0
Tensile Elongation	ASTM-D638	%	3.3	~4	~4	~4	~4
Flexural Strength	ASTM-D790	MPa	61	78	98	84	90
Flexural Modulus	ASTM-D790	GPa	2.1	2.5	3.9	2.8	1.9
Lap Shear on A-366 Steel	ASTM-D1002	MPa	25	16	16	14	20
Lap Shear on 2024T Aluminum	ASTM-D1002	MPa	18	13	14	14	20
Tensile Adhesion to A-366 Steel	ASTM-D4541	MPa	42	18	52	18	30
Tensile Adhesion to 2024T Aluminum	ASTM-D4541	MPa	37	10	47	12	24

Typical Physical Properties Comparison Guide

Test specimens are cured at room temperature for two weeks unless otherwise noted. Neat epoxy samples are used for testing. See Resin/Hardener Technical Data Sheet for exact values. Typical values, not to be construed as specifications.

Adhesives are available in two standard colours: No Colour (NC) and Black (BK).

TOOLING EPOXY

Low-Density Fairing Compound

PRO-SET TLG-185/TLG-285 Low-Density Fairing Compound

PRO-SET Tooling Epoxy	
Low-Density Fairing Compound Resin	TLG-185
Low-Density Fairing Compound Hardener	TLG-285

PRO-SET Tooling Epoxy is a 2-part Compound formulated for surface fairing.

The state-of-the-art chemistry behind PRO-SET Tooling Epoxy makes it easy to use, saving on labour and yielding high-quality results. It blends quickly, spreads easily, shrinks minimally and cures within eight hours.

PRO-SET TLG-185/TLG-285 Low-Density Fairing Compound is formulated for filling and fairing composite structures in manufacturing and repair applications. It can be applied in thicknesses up to 12 mm without slumping or sagging. The shear thinning characteristic provides excellent feather edge application. The cured compound is very easy to sand and the filler blend minimizes airborne dust during sanding.

TGL Combined Tooling Resin/Hardener

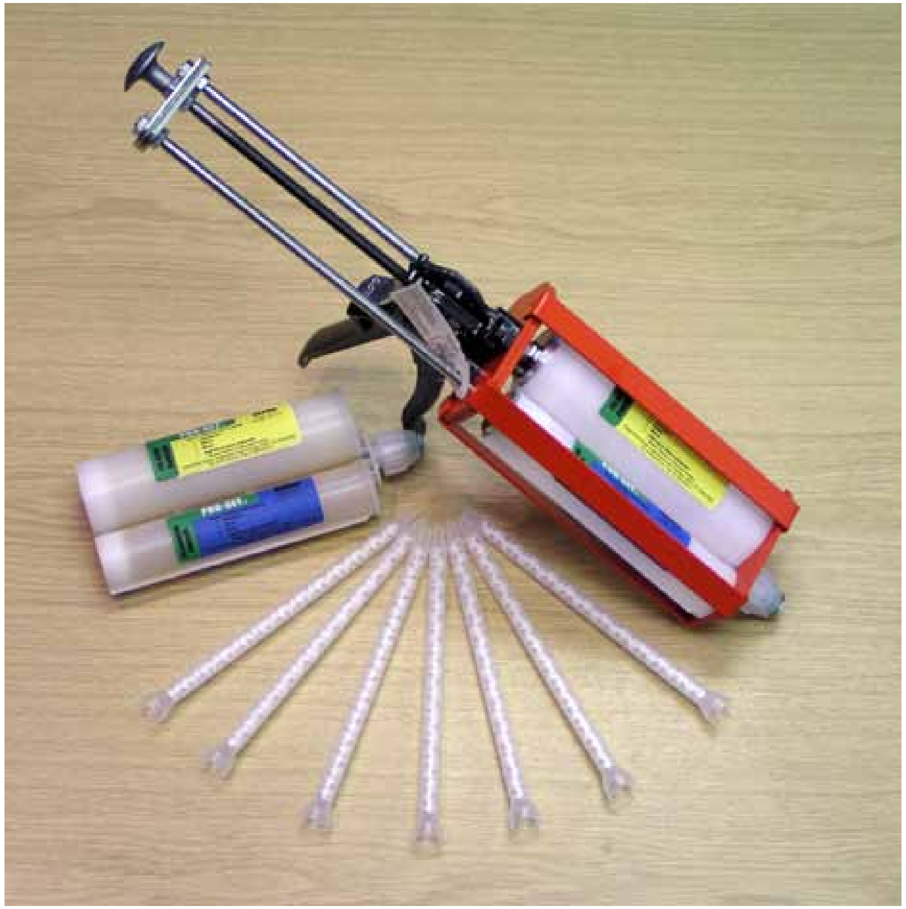
Property	Standard	Units	TLG-185/TLG-285 Low-Density Fairing Compound
Mix Ratio by Volume		R:H	1:1
Mix Ratio by Weight		R:H	1.79:1
150g Pot Life @ 22°C	ASTM 2471	minutes	70 min
500g Pot Life @ 22°C	ASTM 2471	minutes	48 min
Approx working time, 6mm application 22°C		minutes	90 min
Time to Sand, 6mm application 22°C		hours	8 hr
Compression Yield	ASTM D695	MPa	23
Hardness	ASTM D2240	Type D	62

Typical Physical Properties Guide

Test specimens are cured at room temperature to gelation and 25°C for two weeks, unless otherwise noted. Neat epoxy samples are used for testing. See Resin/Hardener Technical Data Sheet for exact values. Typical values, not to be construed as specifications.

Aircraft built by Scaled Composites for Adam Aircraft Industries

PROCESS EQUIPMENT



300-X Manual Dispensing Gun

ADHESIVE DISPENSING GUNS

300-X Manual Dispensing Gun

The two-component cartridge is used with the manual PRO-SET cartridge gun enabling the mixed epoxy to be applied quickly, cleanly and accurately. The gun easily dispenses the high viscosity adhesive and its heavy duty construction ensures precise adhesive application and long operating life.

300-B Pneumatic Dispensing Gun

An air-powered dispenser is available for use with PRO-SET Adhesive cartridges in boatyards and large production assembly units where continuous application of the mixed epoxy is required. Power is supplied by a standard air compressor.

Dispensing with 300-MW Mixing Wands

One mixing wand is supplied with each adhesive cartridge. Extra mixing wands are avalible in packs of 6.

Place the cartridge in the gun and ensure the two pistons are correctly seated against the centres of the seals within the cartridge. Remove the locknut and plugs from the cartridge spouts and position the mixing wand over the spouts and secure with the locknut. The cartridge is then ready to dispense the two epoxy components from the cartridge.

The resin and hardener homogeneously mix together in the mixing wand and exude from the unit as a consistent coloured epoxy indicating that the two materials are discharged in the correct ratio and thoroughly blended. Dispense the adhesive as required.

Model 892-34 impregnator

IMPREGNATORS

PRO-SET impregnators are designed with the custom fabricator or production shop in mind. They can be completely disassembled and are easy to clean. Epoxy is applied to the fabric as it passes through an epoxy bath, and adjustable nip rollers control the epoxy content in the laminate. Epoxy contents from 35% to 55% by weight are possible. The epoxy content control available with these impregnators will reduce resin waste, as well as speed up the laminating process. With the resin dams in place, even small tapes can be used with the large impregnators. Each model is designed to handle a range of fabric sizes and weights.

VH399 Manual Impregnator

We have developed an easy to use fabric impregnator for the boat manufacturer and repair yard. These machines can save a tremendous amount of labour during the laminating process. The operator can easily control the throughput speed, and vary it as necessary to ensure wet out of the fabric. The impregnators have a pair of nip rollers that function like the rollers of a wringer washing machine. However, these rollers have an adjustable gap which allows a controlled amount of resin to stay on the reinforcing fabric. All of the machines have a resin bath tray below the rollers. The fabric can pass through a resin puddle in this tray, and then through the rollers.

VH400 Electric Impregnator

For large laminating projects in which the impregnation of fabrics is almost continuous, a power driven roller impregnator is advantagous. This 1500mm electric machine significantly reduces costs and building time when impregnating woven, stitched or unidirectional fabrics. These impregnators offer extermly high acuracy and efficiency benefits.

Model 892-34 impregnator

Proteus high-altitude aircraft built by Scaled Composites

SUPPLEMENTAL INFORMATION

SHELF LIFE

Epoxy resin and hardener formulations have long shelf life compared to many polymers. The minimum shelf life for the standard INF and ADV resins and hardeners is 2 years. Store at a consistant temperature above 10°C for best results.

STANDARD PACKAGE SIZES

Because the densities of the various resin and hardeners vary slightly, there are slight variations in the package volume, but they are very similar to these nominal weights for each package size.

PRODUCT		PACKAGE SIZE					
		-0	-1	-2	-3	-4	-5
LAM	Resins		1kg	5kg	25kg	225kg	1000kg
	Hardeners		0.286kg	1.43kg	7.16kg (2 x 3.58kg)	64.35kg (3 x 21.45kg)	286kg (2 x 143kg)
INF	Resins			5kg	25kg	225kg	1000kg
	Hardeners			1.37kg	6.86kg (2 x 3.43kg)	61.65kg (3 x 20.55kg)	274kg (2 x 137kg)
ADV	Resins 175/176	400ml Cartridge	2.2kg	22kg			
	Hardeners 273/275/277/276		1kg	10kg			
ADV-170	Resin		0.5kg	1kg	2.5kg	5kg	20kg
	Hardener		0.5kg	1kg	2.5kg	5kg	20kg
TLG-185	Resin		8.2kg	20kg	171.5kg		
TLG-285	Hardener		4.6kg	11.2kg	96kg		

PRO-SET EPOXY HANDLING GUIDE

Refer to the PRO-SET Technical Data Sheets for specific handling characteristics, post cure schedules and physical properties for each of the resin/hardener combinations.

PRO-SET Epoxies are recommended for use by experienced fabricators. If you are new to high-strength laminating epoxies, read this guide thoroughly. If you have additional questions about the handling or use of PRO-SET Epoxies, you are encouraged to contact the Wessex Resins Technical Staff. We strongly recommend that you build representative panels using the proposed laminate schedule under expected workshop conditions to fully understand working characteristics and suitability of PRO-SET Epoxies for your application. Read all safety information before using PRO-SET Epoxies.

SAFETY

To use PRO-SET Epoxies safely, you must understand their hazards and take precautions to avoid them.

Resins may cause moderate skin irritation. Hardeners are corrosive and may cause severe skin irritation. Resins and hardeners are also sensitisers and may cause an allergic reaction similar to poison ivy. Susceptibility and the severity of a reaction varies with the individual. Although most people are not sensitive to resins and hardeners, the risk of becoming sensitised increases with repeated contact. For those who become sensitised, the severity of the reaction may increase with each contact. The hazards associated with resins and hardeners also apply to the sanding dust from epoxy that has not fully cured. These hazards decrease as resin/hardener mixtures reach full cure. To handle PRO-SET Epoxies safely, we recommend that you observe the following precautions:

1. Avoid contact with resin, hardeners, mixed epoxy and sanding dust from epoxy that is not fully cured. Wear protective gloves and clothing whenever you handle epoxies. If you do get resin, hardener or mixed epoxy on your skin, remove it as soon as possible. Resin is not water soluble—use a waterless skin cleanser to remove resin or mixed epoxy from your skin. Hardener is water soluble—wash with soap and warm water to remove hardener or sanding dust from your skin. Always wash thoroughly with soap and warm water after using epoxy. Never use solvents to remove epoxy from your skin.

   Stop using the product if you develop a reaction. Resume work only after the symptoms disappear, usually after several days. When you resume work, improve your safety precautions to prevent exposure to epoxy, its vapours and sanding dust. If problems persist, discontinue use and consult a doctor.

2. Protect your eyes from contact with resin, hardeners, mixed epoxy, and sanding dust by wearing appropriate eye protection. If contact occurs, immediately flush the eyes with water under low pressure for 15 minutes. Seek medical attention.

3. Avoid breathing concentrated vapours and sanding dust. PRO-SET Epoxies have low VOC content, but vapours can build up in unvented spaces. Provide ample ventilation when working with epoxy in confined spaces. When adequate ventilation is not possible, wear a HSC (Health & Safety Commission) approved respirator with an organic vapour cartridge. Provide ventilation and wear a dust mask when sanding epoxy, especially uncured epoxy. Breathing uncured epoxy dust increases your risk of sensitisation. Although epoxy cures quickly to a sandable solid, it may take over two weeks at room temperature, or post-curing, to cure completely.

4. Avoid ingestion. Wash thoroughly after handling epoxy, especially before eating or smoking. If epoxy is swallowed, drink large quantities of water—DO NOT induce vomiting. Because hardeners are corrosive, they can cause additional harm if vomited. Call a physician immediately.

5. Clean up spills with a scraper, collecting as much material as possible. Follow up with absorbent towels. Use sand, clay or other inert absorbent material to contain large spills. DO NOT use saw dust or other fine cellulose materials to absorb hardeners. Clean resin or mixed epoxy residue with acetone, lacquer

thinner or alcohol. Follow all safety warnings on solvent containers. Clean hardener residue with warm soapy water. DO NOT dispose of hardener in waste containing saw dust or other fine cellulose materials—spontaneous combustion can occur.

6. Dispose of resin, hardener and empty containers safely. Puncture a corner of the can and drain residue into the appropriate new container of resin or hardener. Do not dispose of resin or hardener in a liquid state. Waste resin and hardener can be mixed and cured (in small quantities) to a non-hazardous inert solid. CAUTION! Pots of curing epoxy can get hot enough to ignite surrounding combustible materials and give off hazardous fumes. Place pots of mixed epoxy in a safe and ventilated area, away from workers and combustible materials. Dispose of the solid mass only if cure is complete and the mass has cooled. Follow local disposal regulations.

7. PRO-SET products are intended for use by professional or technically qualified persons only. Regularly updated Safety Data Sheets (SDS), are available from your PRO-SET distributor. Refer to the SDS and product label for specific first aid procedures and product safety information.

For additional safety information contact Wessex Resins.

HANDLING PRO-SET EPOXIES

This section is intended to provide an understanding of the general handling characteristics of PRO-SET Epoxies. Refer to the PRO-SET Resin/Hardener Technical Data Sheets for specific handling characteristics, post cure information and cured physical properties.

Combining PRO-SET Epoxy resin and hardener starts a chemical reaction that gradually changes the mixed ingredients from a liquid to a solid. Careful measuring and thorough mixing are **essential** for a complete reaction to occur.

Dispensing

Most problems related to curing of the epoxy can be traced to either inadequate mixing or the wrong ratio of resin and hardener. To simplify metering, we recommend using calibrated pumps to dispense resin and hardener. The PRO-SET 307 High-Capacity Positive Displacement Pump is calibrated to dispense the proper working ratio of all PRO-SET liquid Resin/Hardener combinations.

Production quantity dispensing systems are available from several manufacturers. Contact the technical staff for recommendation.

Before you use the first mixture on a project, verify that the pumps are delivering the proper ratio. Refer to the verification procedure in the instructions that come with the pumps. Recheck the ratio periodically or anytime you experience problems with curing. Production facilities should check pump ratios on a regular basis.

To measure by weight or volume, refer to the PRO-SET Resin/Hardener Technical Data sheets or hardener label for the correct resin-to-hardener ratio.

Mixing

Mixing epoxy with error-free results involves three separate steps:

1. Dispense the proper proportions of PRO-SET Resin and Hardener into a clean plastic or paper mixing container. Never use glass or foam containers because of the danger of exothermic heat buildup. Begin with a small batch if you are unfamiliar with the pot life or coverage of the epoxy.

2. Stir the two ingredients together thoroughly until blended to a uniform, homogeneous consistency. Scrape the sides, bottom and inside corners of the pot as you mix. If you use a power mixer, thoroughly scrape the sides and corners of the mixing pot while mixing. Operate the mixer at a slow speed to prevent stirring air into the epoxy mixture.

3. Mix resin and hardener thoroughly in a mixing pot before transferring it to a roller pan, impregnator or part. Transfer the mixture immediately to maximize working time. If using additives, such as pigments and fillers, thoroughly stir in before transferring the mixture from the mixing pot.

CAUTION! Heat is generated by the chemical reaction that cures epoxy. A plastic mixing cup full of mixed epoxy will generate enough heat to melt the cup, if left to stand for its full pot life. If a pot of mixed epoxy begins an uncontrolled exotherm, quickly move it outdoors or to a safe, well ventilated area. Avoid breathing the fumes. Do not dispose of any epoxy mixture until the reaction is complete and has cooled.

Pot Life

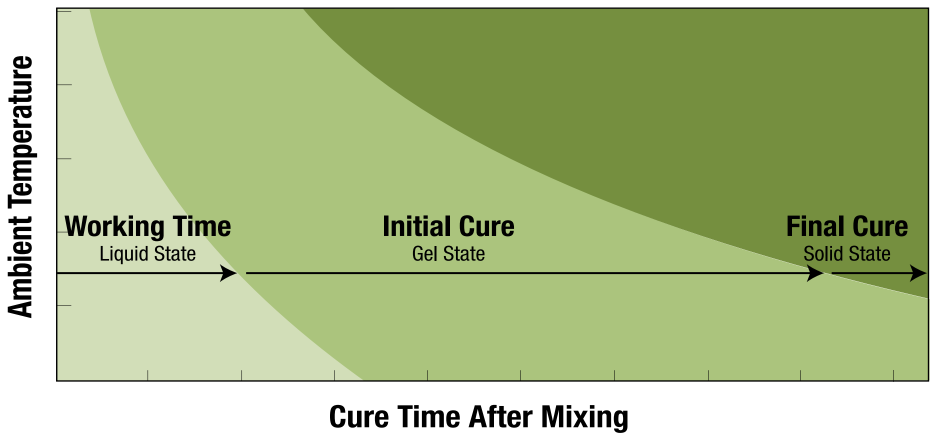
Selection of a resin/hardener combination may be based on the length of its pot life. Pot life is a term used to compare the relative rate of reaction or cure speed of various resin/hardener combinations. By definition, it is the amount of time a given mass of mixed resin/hardener will remain in the liquid state at a specific temperature.

For comparison, we determine the pot life of an individual resin/hardener combination based on either a 100 or 500g mixture in a standardised container, at a consistent temperature. Pot life is not intended to directly correlate to actual working life or assembly time, but indicates a resin/hardener combination's potential working time relative to other resin/hardener combinations. An epoxy mixture's mass and temperature during the manufacturing or assembly process contribute to its actual working life. See CONTROLLING CURE TIME.

Curing

The transition period of an epoxy mixture from a liquid to a solid is called the cure time. It can be divided into three phases: working time—also called open time or wet lay-up time (liquid state), initial cure (gel state) and final cure (solid state). The speed of the reaction, the length of these phases and the total cure time vary relative to the ambient temperature.

Epoxy Cure Phases



All PRO-SET Epoxies go through the same three phases of cure. The higher the ambient temperature, the shorter each of the phases and overall cure.

1. Working Time

Working time is the assembly time of mixed epoxy. It is the portion of the cure time, after mixing, that the epoxy will remain in a liquid state and be workable. The end of the working time marks the last opportunity to apply clamping pressure to an assembly and obtain a dependable bond.

2. Initial Cure Phase

The working time is over when the mixture passes into an initial cure phase and has reached a gel state. It may be hard enough to be shaped with files or planes, but too soft to dry sand. Post-cure heating may begin once the mixture has reached an initial cure.

3. Final Cure Phase

In the final cure phase the epoxy mixture has cured to a solid state and, if not post-cured, will continue to cure over the next couple of weeks at room temperature. Post-curing at elevated temperatures will shorten the final cure phase of PRO-SET Epoxies, and is necessary for components requiring the best thermal properties.

Controlling Cure Time

Several factors affect cure time and can be manipulated to extend the length of the cure time and working time.

1. Type of Hardener

Each resin/hardener combination will go through the same cure phases, but at different rates. Choose the hardener that gives you adequate working time for the job you are doing at the temperature and conditions you are working under. PRO-SET Hardeners may also be mixed to provide a custom blend with an intermediate cure time. Refer to the PRO-SET Resin/Hardener Technical Data Sheets to compare the curing and handling characteristics of blended hardeners.

2. Mixed Quantity

Mixing resin and hardener together creates an exothermic (heat producing) reaction. A larger quantity of mixed epoxy will generate more heat and yield a shorter working time and overall cure time. Smaller batches of epoxy generate less heat than larger batches and have longer cure times. Therefore, a thicker joint, thicker laminate or layer of epoxy will cure quicker than a thin layer.

3. Container Shape

Heat generated by a given quantity of epoxy can be dissipated by pouring the mixture into a container with greater surface area (a roller tray, for example), thereby extending the working time. Since the mixed epoxy will cure at a faster rate while it's in the mixing pot, the sooner the mixture is transferred or applied, the more of the mixture's working time will be available for assembly.

4. Temperature

Heat can be applied to or removed from the epoxy to shorten or extend working and cure times. This can be especially beneficial when assembling very large or complicated components that require maximum working time and minimum final cure time. Be sure you fully understand the effects of heating and cooling on the mould before implementing these techniques.

Before mixing, moderate heat can be applied to the resin and hardener to shorten the epoxy's working time. Conversely, a cooler box can be used to draw heat from a roller pan to extend working time (contact Wessex Resins for information about building cooler boxes). For larger operations, impregnating machines with water cooled rollers are available to extend working time.

After the epoxy is applied, a fan can be used to draw heat from the lay-up or application and extend the epoxy's working time. The tooling itself can be designed to both extend working time and shorten cure time. It is possible to build tooling with tubing embedded. During the layup, cool water pumped through the mould draws heat from the lamination, extending the working time. When the layup is complete, hot water or steam pumped through the mold will speed the cure of the laminate.

Moderate heat (hot air gun or heat lamp) applied to the assembly will shorten the epoxy's cure time. Heat can be applied as soon as the assembly is completed, but most often heat should be applied after the epoxy has reached its initial cure. Heating epoxy that has not reached its initial cure will lower its viscosity, causing the epoxy to run or sag on vertical surfaces. In some processing procedures, heating too soon can lower the resin content of the laminate to unacceptable levels. In addition, heating parts that contain porous materials (wood or low density core material) can cause the substrate to "out-gas." When air in the porous material expands and passes through the curing epoxy, it can leave bubbles or pinholes in the cured epoxy.

Regardless of what steps are taken to control the cure time, thorough planning of the application and assembly will allow you to make maximum use of the working life of the epoxy mixture.

Post-Curing

Resin/hardener combinations reach an excellent degree of cure for most applications with only a room temperature cure. Resin/hardener combinations with LAM-251-HT Hardener require an elevated temperature post-cure to achieve optimal physical properties.

Post-curing is the controlled heating of an epoxy laminate—after it has reached or passed its initial cure stage—to improve the physical strength and thermal properties of the cured epoxy. Each PRO-SET Resin/Hardener combination has potential maximum cured properties that can only be achieved by post-curing the laminate above a minimum target temperature.

For each resin/hardener combination there is a range of target temperatures (above the minimum target temperature) that will allow the laminate to reach 100% of its potential cured properties.

Each target temperature within the range has a corresponding minimum hold time. Higher target temperatures require shorter hold times—lower target temperatures require longer hold times.

Maximum properties will not be reached if the actual post-cure temperature is below the minimum temperature in the range. However, even with post-cure temperatures below the minimum target temperature, most resin/hardener combinations will achieve increased properties.

Determine the post cure temperature for a resin/hardener combination by the desired physical properties of the component, or by the limits of the equipment to reach or hold a target temperature. Thermal shock can induce flaws in the laminate. To avoid this, increase the temperature slowly and do not exceed the maximum target temperature. *Refer to the specific PRO-SET Resin/Hardener Data Sheet for information on post cure temperature and cured physical properties.*

APPLICATION TECHNIQUES

Primary Bonding/Wet Lay-Up

PRO-SET Laminating Epoxies are designed for primary bonding of composite materials like fibreglass, carbon, aramid and various core materials. Fabrics may be wet out by hand or by roller impregnating machines. Since each resin/hardener combination will have a different viscosity, test a combination for its suitability with a particular fabric and impregnating machine setup.

Fabrics recommended for use with PRO-SET Epoxies should be classified as epoxy compatible. Avoid fabrics with styrene soluble binders or that are compatible only with styrenated resins.

Vacuum Bag Laminating

Vacuum bagging is an excellent clamping method for composite construction using PRO-SET Epoxies. Regulating the amount of vacuum pressure permits control of the resin/fibre ratio and can produce a more dense laminate, with a higher fibre volume. Generally, the higher the vacuum pressure, the lower the resin content. The optimum resin/fibre ratio for a particular component will be between 30% and 50%. A lower ratio will result in a lighter composite. A higher ratio will be heavier, yet yield higher moisture exclusion effectiveness. Various bleeder and absorber materials used in vacuum bag laminating can also influence the resin/fibre ratio. Building test panels is recommended to determine the proper vacuum bagging material schedule and vacuum pressure for a particular component.

Infusion

PRO-SET Infusion Epoxies are used for resin infusion, VARTM, RTM and other closed moulding applications. Choose the resin/hardener combination that will provide suitable gel time for the part and process. Because of the many variables involved, these techniques require testing to determine the most suitable procedure and the proper resin/hardener combination for each part.

Release Fabric

In areas where you plan to do secondary bonding or additional coatings, use a release fabric (such as peel ply) over the layup. When peeled from the cured or partially cured surface, release fabric leaves a fine texture, free of contaminates and amine blush. After the laminate reaches initial cure and the release fabric is removed, the laminate surface is ready for bonding without further preparation. Using release fabric eliminates the need for washing and sanding in preparation for secondary bonding or coating. A laminate may be built up in several consecutive layups over period of days. Use release fabric after each day's lay-up and remove it prior to the next layup. When complete, the built up layers of laminate can be post cured together.

Not all release fabrics have an epoxy compatible coating or a texture suitable for secondary bonding with epoxy. Before building a part, test for the ability to bond to a surface prepared with the intended release fabric at the proposed post-cure temperature.

Post-Cure Schedules

During a post-cure, the temperature of the laminate is slowly raised to the post-cure target temperature, held for a period of time, then slowly lowered to room temperature. Post-cure schedules vary depending on the resin/hardener combination, the desired laminate physical properties, and the capability of the post-cure equipment to reach and maintain a target temperature.

Elevated temperature cure may begin as soon as the laminate is laid up, but with precautions. Keep in mind that as the uncured epoxy warms, it becomes more fluid and may drain from vertical laminates or result in a reduced resin-to-fibre ratio in some processes. In addition, in thicker laminations, the heat of the post-cure added to the exothermic heat generated by a large mass of curing epoxy may be high enough to damage the laminate or mold. For these reasons, post-cure should begin after the epoxy reaches an initial cure at room temperature.

The post-cure target temperature is usually determined by the mechanical or thermal properties desired, but may also be determined by limitations of the post-cure equipment, or the ability of core materials or the mould to withstand post-cure temperatures. Although minimum recommended post-cure temperatures may be lower, 60°–82°C is the most effective range for post-curing PRO-SET Epoxies (other than when LAM-251-HT hardener is used). The target temperature determines the maximum potential properties a resin/hardener combination can reach. The highest gain in properties occurs within 8 hours, with diminishing gain up to 16 hours. Use the resin/hardener technical data sheets as a guide for determining cure schedules.

The laminate thickness will determine the rate of temperature increase. A thick laminate may require a hold cycle to allow the temperature to normalise

Start of a Farr 40 race

throughout the laminate. A core can insulate a portion of the laminate, causing that portion to lag behind the average temperature rise. Use thermocouples to monitor the temperature at various locations on the component during post-cure.

Increase the laminate temperature at a controlled rate so the laminate temperature does not exceed the thermal properties of the epoxy in the laminate. As the laminate is heated, the epoxy will continue to cure. The temperature ramp rate should be slow enough to allow for this additional epoxy cure, pushing the thermal properties of the epoxy up ahead of the laminate temperature. If the laminate temperature exceeds the thermal properties of the epoxy, surface distortion or laminate print through may occur.

Observe the following guidelines to avoid thermal shock during the post-cure cycles:

1. Increase the temperature from room temperature at a rate of 8°–11°C per hour.
2. At every 22°C increase in temperature, hold that temperature for an extra hour to allow interior laminate temperatures to equalise. Resume the temperature increase of 8°–11°C per hour.
3. Continue this cycle until the post cure target temperature is reached.
4. Hold the target temperature for a minimum of 8 hours (other than when LAM-251-HT hardener is used). The physical and thermal properties of the component will continue to improve until 100% of the potential properties are reached. Lower target temperatures require longer post cure times to reach 100%.
5. Decrease the temperature at a rate of 11°C per hour.
6. Hold at 35°C for two hours to allow for normalisation.
7. Turn off heat and allow to cool to room temperature. This schedule is recommended when curing a lighter laminate. The temperature ramp speed should be decreased for moulds, plugs and heavy laminates. We recommend building test panels of the finished laminate schedule to determine the ideal post-cure cycle. Thermocouple wires embedded in the test laminate will measure the temperature lag during the post-cure.

Heating Methods

Post-cure heating techniques vary depending on the size of the component and mould, the number of components being built or on the resources available for space and equipment. If resources are available, a fully insulated oven with an electric or vented gas or oil heater provides the greatest control over post-cure variables.

Radiant heaters that generate long wave infrared radiation can be used to heat the component without the use of an enclosure. This post-cure technique is often used on large components, when space is limited or when a limited production does not justify the cost of an enclosure. Temperature is monitored by surface mounted thermometers and the heaters are repositioned over the component as necessary to provide an overall post-cure. WARNING! It is difficult to accurately control the rate of temperature change and maintain a uniform target temperature with radiant heating. This may result in laminate that does not have uniform physical properties. This technique may also result in more print through of the laminate.

Post Curing In Moulds

Generally, components are post-cured in the mould in which they were laminated. Moulds that are subject to repeated use should be post-cured at a higher temperature than that required for the finished component. This allows the part to be post-cured in the mould at a temperature below the mould's HDT, thereby avoiding distortion of the mould, mould surface or the component during the component post-cure.

Plugs used to build moulds should be post-cured at higher temperatures than the mould to avoid distortion of the plug or plug surface while the mould is being post-cured. Check plugs for fairness after post-curing and fair as necessary before the mould is fabricated.

Surface Preparation

The success of secondary bonding depends not only on the strength of the epoxy, but also on the ability of the epoxy to mechanically key into the surface of the material rather than chemically bond to it. If you are bonding to a surface that has not been properly prepared with release fabric, the following surface preparation steps are critical to any secondary bonding:

1. Removing Amine Blush

Amine blush is a by-product of the epoxy curing process. This wax-like film may form during the initial cure phase. The blush is water soluble and can easily be removed, but can clog sandpaper and inhibit subsequent bonding if not removed. To remove the blush, wash the surface with clean water and an abrasive pad. We recommend 3M Scotch-brite™ 7447 General Purpose Hand Pads. Dry the surface with plain white paper towels to remove the dissolved blush before it dries on the surface. After washing with the abrasive pad, the surface should appear dull. Sand any remaining glossy areas with 80-grit sandpaper. If a release fabric is used, amine blush is removed when the release fabric is removed.

2. Cleaning

Surfaces must be free of any contaminants such as grease, oil, wax or mould release. Clean contaminated surfaces with silicone and wax remover or acetone. Wipe the surface with clean paper towels before the solvent dries. Clean surfaces before sanding to avoid sanding the contaminant into the surface. CAUTION! Provide plenty of ventilation and follow all safety precautions when working with solvents.

3. Drying

Bonding surfaces must be as dry as possible for good adhesion. If necessary, accelerate drying by warming the bonding surface with hot air guns or heat lamps. Use fans to move the air in confined or enclosed spaces. Watch for condensation when working outdoors or whenever the temperature of the work environment changes.

4. Sanding

Sand non-porous surfaces (metal, FRP laminate, cured epoxy, hardwoods, etc.) thoroughly to obtain an abraded surface. 80-grit aluminium oxide paper will provide a good texture for the epoxy to key into. Be sure the surface to be bonded is solid. Remove any flaking, chalking or blistering before sanding. Wear a dust mask! Remove all dust after sanding. Laminate surfaces can be textured by using release fabric during fabrication. This may eliminate the need for additional sanding.

Secondary Bonding

Secondary bonding operations include the bonding of structural members, blocking or additional fabric reinforcing, coating, fairing or filleting to a previously cured or existing component. Once the component has cured to a solid state, a new application of epoxy will not chemically link with it, so the surface of the component must be washed and sanded (if it was not prepared with release fabric) to provide the proper surface for mechanical secondary bond.

PRO-SET Adhesive is a two-part, thixotropic epoxy adhesive designed for secondary bonding and assembly of composite components. It cures fully at room temperature and it can be post-cured if parts are to be assembled before they are post-cured.

PRO-SET laminating resins and hardeners can be used for tabbing and taping operations either before or after post cure. Choose the resin and hardener combination that will provide the viscosity and cure speed combination necessary for the fabrics being used and to minimize drain out.

Surface preparation for paint

Wet-sand the surface to remove any flaws and provide a texture for the paint to key into. If you are using a filling or sandable primer, use 100-grit paper. Use 220-320 grit paper if no primer is used. The thinner the paint film thickness, the finer the grit of sandpaper needed. Rinse the surface with clean water and dry thoroughly. Rinse water should sheet without beading up or fisheyeing, which could be a sign of local contamination. Re-wash with solvent if necessary and wet-sand. Allow the surface to dry thoroughly before painting.

PRO-SET Epoxies provide an excellent base for most paint systems. Linear polyurethane paints have proven to be the most durable protection over epoxy. Regardless of the paint system used, thorough preparation of the surface is essential for good paint adhesion and a smooth finish. For coating, follow the paint manufacturer's instructions.

Gelcoats

We have had good results with various in-mould polyester gelcoats. Because of their superior resistance to ultraviolet degradation, polyester gelcoats are preferred over epoxy gelcoats for exterior finish applications. Check with your polyester gelcoat supplier for recommendations and test to determine product suitability and application technique.

Some fabricators have reported good success using a 2 part linear polyurethane paint sprayed directly onto the mould surface. This coating is allowed to cure and the epoxy laminate is applied directly to the paint

An epoxy gelcoat is sometimes preferred for plugs and moulds. Contact the Wessex Resins Technical Staff for custom product recommendations.

We recommend that each brand of gelcoat or in-mould coating and/or tie coat technique be tested for suitability in a specific application. If you have any questions about testing, call the Wessex Resins Technical Staff.

QUALITY ASSURANCE CONSIDERATIONS

This section offers quality control measures that can be employed by fabricators, large and small, to assure consistent high performance of PRO-SET Epoxies.

Common Problems

The vast majority of problems encountered when working with an epoxy system can be traced to either improper mix ratio or insufficiently mixed resin and hardener. Metering the two components at the proper mix ratio and thoroughly blending them helps ensure consistent, high-quality results.

To a lesser extent, problems may also arise from not properly compensating for changes in temperature. It is important to understand how changes in temperature can affect the cure characteristics of epoxy and how to counteract those effects.

Proper Mix Ratio

PRO-SET pumps are designed to meter the correct ratio of resin and hardener for standard PRO-SET combinations. With any metering system, a frequent check of the pump ratio is recommended. You can use graduated containers to check the metered volume or a scale to check the ratio by weight. If the ratio is not within the acceptable range for the products you are using, corrective action must be taken. Re-check the ratio anytime you experience problems with curing. Production facilities should check pump ratios on a regular basis.

Luis and Clark carbon fibre violin

Epoxy Ratio and Hardness

Each resin/hardener combination will achieve optimum working, cure and mechanical properties at a specific mix ratio. Refer to the Technical Data Sheets for the acceptable range for the resin/hardener combination you have chosen. If the actual mix ratio deviates from this ratio range, the physical properties of the resin system will decline as the ratio deviates from the acceptable range.

To check the cure of the epoxy we use the ASTM D-2240 method for Rubber Property—Durometer Hardness. This method is recommended for quality control purposes and not for establishing specifications. This test is performed using a durometer measuring the D scale. The indenter needle is pressed into the cured epoxy sample and the resistance is recorded on an indicator. Durometers are available from industrial supply companies. Any instrument meeting the ASTM D-2240 requirements can be used. Some resin manufacturers specify Barcol hardness readings. However, we feel the D scale Durometer is more sensitive than the Barcol tester and is more appropriate for epoxy testing. Unfortunately, there is no direct conversion from the D scale to Barcol scales.

It is often a good idea to prepare a special quality control sample for testing and to keep quality control samples of cured epoxy for future reference. It can be as easy as pouring a portion of the mixed epoxy you are using into a mould or suitable container. Label this sample and cure it under the same conditions as your project. It may be sufficient to check the hardness right on the part you are building, as long as there is a flat area large enough to use the durometer.

A fully cured sample of epoxy will usually show a durometer D scale hardness of 81-90. A sample that has not had sufficient time to cure will have a lower hardness. However, if the hardness does not increase after a reasonable amount of time, there are several possible causes which should be investigated. The temperature may be too low to allow the epoxy to cure properly, the epoxy may have been mixed at the wrong ratio, or it may have not been mixed thoroughly, resulting in localized areas of off-ratio material.

Thorough Mixing

When using a mechanical mixer to blend large batches of epoxy, it is crucial to scrape the sides and bottom of the container to ensure thorough mixing.

Compensating for Temperature Effects on Epoxy Curing

The cure and pot-life information for PRO-SET Resin/Hardeners combinations are shown on the Technical Data Sheets.

Low temperatures can increase working time, time to full cure and resin viscosity. Higher resin viscosity due to low temperatures can cause pumps to meter off ratio. It may be more difficult to thoroughly mix a very thick resin and hardener batch. It may also be more difficult to wet-out the fabric with very thick epoxy. The extended cure time can leave the epoxy vulnerable to damage if clamping pressure is removed too early.

Higher temperatures will reduce working time, cure time and resin viscosity. The builder should carefully evaluate the working conditions, size of job and number of workers in choosing the correct resin/hardener combination.

PRO-SET EPOXY TESTING TERMINOLOGY AND METHODS

PREPARATION OF TEST SPECIMENS

All data is collected from unmodified, mixed and cured epoxy. Pure epoxy mixtures are used to eliminate the effect of fibres or filler.

All of the mechanical data reported is based on epoxy mixed at the target ratio and cured under the conditions specified in the top row of the table on the product data sheets.

The published data is based on the same test conducted several times on multiple specimens, generating average result numbers. Averages, not highest values are reported. These averages are rounded to appropriate number of significant figures.

ASTM standards are followed for all testing. When comparing another manufactures' product to PRO-SET be sure to note if they used the same standardised test.

HANDLING PROPERTIES

Pot Life is the amount of time a mixture of resin and hardener has at a workable viscosity while in the mixing container. Pot life is determined using 150g and 500g samples in a standardised container at 22°C, 25°C and 29°C. Both mass and ambient temperature affect the rate at which an epoxy system will cure. Pot life should be used only for comparative purposes when evaluating an epoxy system's cure time.

Working Time is the amount of time the viscosity of the epoxy remains low enough to be processed. It is determined using a Gel Timer which employs a spindle traveling through an 3.2mm thick volume of liquid epoxy. Working time is the amount of time the spindle can travel through the epoxy without leaving an indent in the curing epoxy.

Viscosity is a fluid's resistance to a shear force and can be thought of as how easily a fluid flows. A Rotational Viscometer is used to measure viscosity. A spindle rotates in the epoxy to measure its resistance. A thicker fluid will give the spindle more resistance, indicating a higher viscosity. Since temperature will affect the viscosity, we provide data points at different temperatures as well as graphs that provide viscosity data over a wide range of temperatures.

Manufacturing process and processing temperature are important considerations when determining the required mixed epoxy viscosity. Infusion processes often require very low viscosity to enable good flow whereas a wet layup may require a higher viscosity that allows thorough fabric wet out yet prevents drain out.

Thix Index or Shear Thinning Index is a ratio determined by viscosity measurements taken at 10 and 100 RPM. The low speed reflects how epoxy will flow undisturbed. The high speed measurement indicates how well it will flow when shear force is applied as is often the case during processing.

Mix Ratio is the target ratio of resin to hardener required to achieve published properties and may be different by weight and volume due to the differing densities of the resin and hardener.

Every resin/hardener combination has an optimal target and acceptable range. Please note that the target is often not in the middle of the acceptable range.

Achieving the correct mix ratio can be simplified by using PRO-SET Dispensing Equipment.

Density is the mass divided by volume. We conduct these tests at 25°C so that the density measurement in grams per cubic centimetre (gcm^{-3}) is also equal to the specific gravity.

Hardness is a material's resistance to deformation. This test is conducted with a Durometer utilizing the D scale. A Durometer forces a metal point into the material and provides a numerical reading which corresponds to the resistance at the point. The results of a hardness test are important for comparative purposes and determining the degree of cure.

MECHANICAL PROPERTIES

Compression Yield strength is the stress required to cause plastic deformation. Plastic deformation is the permanent change in shape or size of a solid body without fracture, resulting from sustained stress beyond the elastic limit. Cylinder shaped specimens are placed in a test machine that applies an increasing compressive force until plastic deformation weakens the sample. The highest force recorded prior to deformation is the Compression Yield Strength.

Tensile Strength is the stress that is required to fracture the epoxy and cause a failure. Dog bone shaped specimens are placed in a test machine that applies an increasing tensile force until failure. The highest stress recorded prior to failure is the Tensile Strength.

Tensile Elongation, also referred to as strain, indicates how much the material can "stretch" before it fails. Dog bone shaped samples are placed in a test machine that applies an increasing tensile force until failure. The change in sample length is measured with an extensometer. The point at which the sample fails is the Tensile Elongation.

Tensile Modulus describes the amount of elongation (strain) that results from a specific amount of stress. This property is essentially the stiffness of the material. During the Tensile Strength test, elongation is measured and recorded at the corresponding stress before the material yields. The stress divided by the strain equals the modulus or the slope of the stress/strain curve.

GARC built by Hodgdon Defense Composites.

Flexural Strength is a measurement of the maximum amount of bending stress a sample can withstand before fracturing. The sample is simply supported at each end and an increasing load is applied in the centre. The stress caused by bending is calculated and the amount that results in failure is recorded.

Flexural Modulus is calculated by measuring the deflection of a beam during the Flexural Strength test. In a manner similar to the calculation of Tensile Modulus, the deflection and stress are used to determine the Flexural Modulus.

Lap Shear Strength measures the strength of an epoxy bonded joint when loaded in shear. The test is performed by bonding two metal coupons together with an overlap and then pulling them apart in tension in a test machine. The tensile force creates a shear force in the bond line and the resulting stress is reported as the Lap Shear strength.

Tensile Adhesion Strength is the stress required to fail a bond line with a force perpendicular to the bonded surface. Two aluminium or mild steel cylinders of diameter 25mm are bonded together using the material to be tested. A device is threaded onto both adherends and applies a pulling force to the bonded joint. The load required to fail the bond is divided by the bonded surface area and the resulting stress is reported on the data sheet as the Tensile Adhesion strength.

THERMAL PROPERTIES

Glass Transition Temperature (Tg) is a very useful property for understanding the thermal characteristics of an epoxy resin system. The Tg is the temperature at which the epoxy changes from a glassy (solid) state to a soft, rubbery state. It can be considered the point at which a measurable reduction in physical properties occurs resulting from exposure to elevated temperatures.

Be aware that Tg values can be reported after a second heat. The second heat is the process of testing the sample after it has been exposed to an initial first heat which resulted in an elevated temperature, 200°C, post cured sample. A second heat Tg value is not representative of your sample unless you have replicated the 200°C cure schedule that was used for the first Tg test.

Tg DMA Onset Storage Modulus and Peak Tan Delta

The Dynamic Mechanical Analyzer (DMA) determines the Tg using a mechanical method. The test sample is placed into a three point bending fixture and a cyclical load is applied. The temperature of the sample is increased and the change in the deflection is measured. As the temperature is increased during the test, the response of the sample changes. The sample's response is plotted using three different graphs based on how the bending energy is transferred into the sample: storage modulus, loss modulus, and the tan delta.

Storage Modulus is the elastic response. The recovered part of the energy originally put into the sample.

Loss Modulus is the energy that is absorbed by the sample due to friction and internal motion.

Tan Delta is the ratio of loss modulus to storage modulus, the dampening character of the sample.

When epoxy is below its Tg, the storage modulus is high and the loss modulus is low. The sample releases energy efficiently and does not absorb energy well due to its stiffness. When the sample gets closer to its Tg, the storage modulus decreases. Energy is now absorbed into the sample, driving the loss modulus higher.

Tg Onset Storage Modulus is a conservative value indicating a measured loss of stiffness.

Tg Peak Tan Delta is the highest measured Tg value.

Tg DSC Onset–First Heat

While a DMA measures thermal properties of a sample via mechanical means, a Differential Scanning Calorimeter (DSC) machine measures the heat flow in and out of a sample to determine its Tg. This test is conducted by placing a fully cured sample into a small pan in the DSC and heating it to 200°C at a rate of 10°C per minute. The heat flow into the sample is measured and compared to an empty reference pan. The difference in heat flow is measured and plotted. An inflection occurs in the plotted curve at the Tg; the Onset is measured at the beginning of this inflection.

Tg DSC Ultimate

Ultimate Tg is the highest Tg value that can be attained for a particular epoxy system. In order to achieve this temperature resistance in an application the epoxy must be post cured at a pre-defined elevated temperature for a specific amount of time. See the Technical Data Sheet (TDS) for a specific resin/hardener combination, or contact our Technical Department.

Heat Deflection Temperature

Heat Deflection Temperature (HDT) is the temperature at which the epoxy will deform under constant load.

A sample is submerged in oil at a carefully calibrated temperature and subjected to 1.82 MPa of bending stress in the centre. The temperature of the oil is then gradually raised until the bar deflects 0.25mm in the centre. This temperature is considered to be the heat deflection temperature.

HDT of Laminate

The HDT of Laminate is the temperature at which a typical 3.2mm epoxy/fibreglass laminate will deform under constant load with the same test parameters as above. The HDT of a laminate is so much higher than a neat resin that it will not deform even at the test's maximum temperature of 300˚C.

Motorcycle refurbished by Rafa Abella.

Wessex Resins & Adhesives, Cupernham Lane,
Romsey, Hampshire, SO51 7LF
+44(0)1794 521111 / pro-set.co.uk

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